Modelling Sustainable Systems and Semantic Web

Systems and their Development

Lecture in the Module 10-202-2312
for Master Computer Science

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April 2022

What is a System?

See also the Handout on "Systems, Organisations, Mangement".

System definition

A *system* is a *delimited set of components*. Their interaction realises a *qualitatively new function* (emergent function) and thus constitutes *a new unified whole*.

The systemic approach is a form of reduction of the complexity of the totally interconnected real-world (*reality* for short).

What is a System?

Three dimensions of reduction to the essentials.

(1) Outer demarcation of the system against an *environment*, reduction of these relationships to input/output relationships (specifications and interfaces) and guaranteed throughput.

(2) Inner demarcation of the system by combining subareas to *components*, whose functioning is reduced to "behavioural control" via input/output relations (specifications and interfaces).

(3) Reduction of the relations in the system itself to "causally essential" relationships.

What is a System?

This reduction is essential for both the *description* of real-world contexts and for their *operational control*.

In this understanding, systems are to be considered as a **unit of analysis/description (modelling) and execution (operation)**, emphasising the *structuredness* and thus *decomposability* of the system in the analytic dimension on the one hand, and the *interdependence* and thus *indecomposability* in the operational dimension on the other.

In the assembled system in addition to the components, the *connecting elements* also play an important role. They mediate the *flow of energy, material and information* that is required for the operation of each component.

Systems and the Theory of Dynamical Systems

The Theory of Dynamical Systems is an important mathematical description tool for the operational dimension of the system model used to *quantify its laws of motion*.

In the simplest case (Handout ch. 6), the elements of such a dynamical system are atomic. In the general case, the parts (components) of the dynamical system come with their own dynamics, which are combined to form the dynamics of the overall system.

As reduction to essentials takes place, the dynamics of the components do **not** enter with their full complexity into the modelling of the overall system.

Systems and Practice

Systems are a part of the complex relationships of practice.

Analysis and modelling as human thinking activities not only have a *mental quality*, but also a *practical* one. The goal of modelling is to influence real-world processes; the *criterion of "truth"* is formed from practical experience, how successful the mental modelling and *intended transformation of the real-world substrate* are related.

However, this experience itself can only be communicated intersubjectively in language form and is thus itself of mental quality.

A coherent concept of a system must combine both dimensions – language shapes expressiveness, expressive practices shape language.

Systems and Autonomy

The concept of system in such a version suggests a certain *autonomy of systems*.

On the other hand, the system concept is self-similar – components can again be considered and analysed as systems.

However, this is done under a *different reduction to essentials* than for the overall system.

In such an understanding, components are part of an overall system in which the component dynamics influence each other and thereby *jointly produce the emergent function of new quality* of the overall system. This undermines the notion of autonomy (of the components as systems in their own).

Closed and Open Systems.

Open Systems

Open systems can be modelled like closed ones if additionally a qualitatively and quantitatively determined **throughput of energy, matter and information** is postulated.

Altshuller's Law of Energy Conductivity.

A necessary condition for the viability of a technical system is the flow of energy through all its parts.

This external throughput is often constitutive for the inner system structure through resonance and dissonance phenomena of amplification and extinction of inner dynamics.

Altshuller's Law of Coordination of the Rhythm of the Parts.

A necessary condition for the viability of a technical system is the coordination of the rhythms of all parts of the system.

Change the World in a Planned Way

The system concept is a tool in the hands of humans who want to **change the world** following their (intentions, goals and) plans.

11th Feuerbach Thesis (Marx)

Philosophers have only interpreted the world differently, it is a matter of changing it.

Die Philosophen haben die Welt nur verschieden interpretiert, es kömmt darauf an, sie zu verändern.

But: The world is in constant motion and also permanently changes itself.

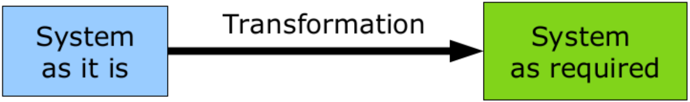
So more precisely: It is a matter of **influencing the development of reality**.

Modelling Systems

Two practical tasks:

(1) Build new system
(2) Rebuild existing system

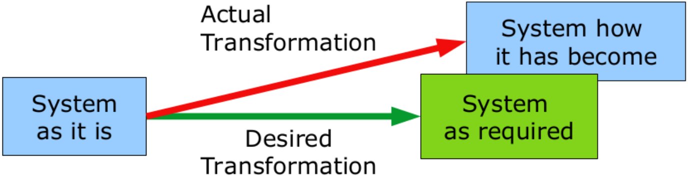
(1) can be consideres as a special case of (2), since every need for a new system comes with at least rough ideas about that new system, so there is also under (1) an at least rough description form of the system to be created.



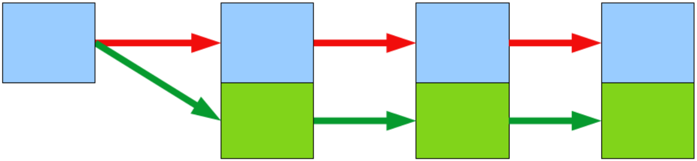
Modelling Systems

This basic scheme fits not only technical systems, but also the modelling of social, socio-ecological and cultural systems, so it is sufficiently universal.

How does such a system evolve over time?



Development of Systems

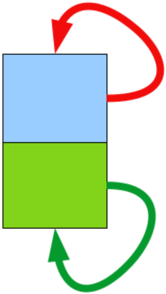


Transitional development as *different versions* of the system over the time.

Development of Systems

But this can also be understood as development in time *of the same system*.

Transitional management versus adaptive management.



Development of Systems

The development of a system can therefore be conceived as a contradiction between an *ideal line of development* and a *real line of development*.

This idea is reflected in the **TRIZ concept of the Ideal Final Result** (IFR – Ideales Endresultat).

In the Theory of Dynamical Systems, system development is conceived as a progression of states, which can be described by a function $f(t)$ with values in a phase space.

The *ideal behaviour* is described by mathematical relationships, such as differential equations of the laws of motion and geometrically displayed as *trajectory*.

System Dynamics

These differential equations and trajectories are part of the *description form of the system* and thus have already been created by *reduction to essentials*.

In the modelling it is assumed that everything essential is taken into account, i.e. that the *real temporal development* $r(t)$ of the system differs from the *ideal temporal development* $f(t)$ only by a small difference $d(t) = r(t) - f(t)$, which is *insignificant for the selected essential*.

While $f(t)$ enables a *quantitative prediction* of the development of the system, the statement that $d(t)$ is "small" or "damped" is a *qualitative statement* of the description form itself.

System Dynamics

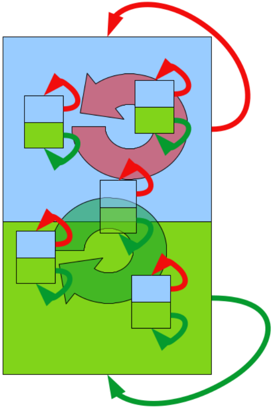
Often one also restricts oneself with $f(t)$ to a *qualitative statement* about the exact position of the trajectories as invariants in the solution space and thus to the statement that $r(t)$ oscillates around these trajectories in a damped manner. These trajectories seem to "magically" attract the real states and are therefore also called *attractors* (steady state equilibrium).

For example, the Earth moves on an elliptical orbit around the Sun in the sense that real deviations from this orbit are compensated.

Coevolution of Systems

What is the relationship between the development

- of the system itself,
- of the components in the system and
- of the relationships in the system?



Coevolution of Systems

The coupling of developments between components is driven by resonance phenomena and coupled to eigentimes and eigenspaces of the inner equations of motion, different for different components.

Altshuller's Law of Non-uniformity of the Development of the Parts of a System.

The parts of a system develop non-uniformly; the more complicated the system, the more non-uniformly develop its parts.